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Method and Device for Operating MIMO Air Interfaces in Mobile Communications Systems

The invention involves a method and device for operating of MIMO air interfaces with mobile communication systems, according the superordinate concept of the independent patent claims.

MIMO (multiple input multiple output) systems are promising new radio transfer techniques for future generations of mobile radios "Beyond 3G." With MIMO systems, one or more HR-modulated signals are beamed on the radio transmission path by a number m of MI antennas and received by a number n of MO antennas. A MIMO channel is therefore construction of m transmission antennas, n reception antennas and a multiplicity of what are generally time variable sub channels between the transmission and receiver antennas which are comprised of diversity channels. By way of example, Figure 1 presents a mobile radio contact with a base station 1 that essentially contains a modulator / demodulator for the data source / sink, a MIMO processor and an HR transmitter / receiver stage, three antennas 2 fed by signal exits A, B, C, a mobile station 3 with basically the same elements as base station 1, two MO antennas 4 and sub channels 5. If the sub channels are statistically independent, the likelihood increases that the transmission signal is to be faultlessly received with the number of the antennas. For an optimal combination of MIMO sub channels realized with MIMO processors, various methods and algorithms, both on the transmitter and receiver end, are known; e.g. as in WO 03 041300 A 1.

The advantages of MIMO methods consist in a clearly more efficient frequency utilization over previous methods (for example 2G, 3G), a reduced EMVU load through fewer transmission performances as well as a high robustness against fading, see, for example, BLAST (Bell Labs Layered Space

Time) technology. To their advantage, MIMO systems are applied to orthogonal multiple access methods such as CDMA,TDMA, FDMA or combinations of these.
Optimal results are gained with MIMO in the Rayleigh channel, i.e. reception only through spread.
The effectiveness of MIMO systems is based on the statistical independence of the MIMO sub channels.
The present invention involves the MIMO air interfaces, specifically antennas. Given reciprocity of the radio channel, the same circumstances apply for the reverse transmission direction.
Densely neighboring antennas with the same polarization have a high correlation of the broadcasted or received signals with the complex correlation factor $\underline{r}$. In order to achieve significant decorrelations by means of space diversity with for example $|\underline{r}| < 0.2$, with conventional mobile radio fixed station antennas with vertical polarization and opening angles of 60° on the horizontal level and 20° on the vertical level, antenna spacings of more than approximately 20 λ horizontally and more than approximately in 3 λ vertically are necessary. Space diversity necessitates large measurements and is therefore less suitable for mobile devices.
Polarization diversity methods offer one solution. For MIMO systems, these are, for example, published in WO 02/058187 A1, WO 02/099995 A2 and U.S. 6 049 705 A (here specifically for mobile radio equipment).
The described transmission equipment works with unchanged orthogonal polarization of the individual MI and MO antennas. These arrangements have the disadvantage that an antenna is required for each MIMO sub channel.

It is the task of the invention to show a method and an arrangement for operating air interfaces in mobile communications systems

in which the space required for antennas and the decorrelation of the sub channels on the air interface are clearly improved.

This task is solved in accordance with the invention by the features of the independent patent claims.

The invention is distinguished by the fact that different polarizations are assigned to the signals to be transmitted and received on the sub channels, and the signals are supplied of a common antenna.

In a preferred design of the invention, an antenna array with spatially narrowly neighboring partial antennas is used as an antenna, in the exemplary embodiment a cross dipole. Preferably, the phase centers of the component antennas coincide.

The assignment of the polarizations of the signals sent out on the sub channels is preferably governed by a control facility. Its polarizations sent out on the sub channels at pre-determined intervals are thereby altered, preferably synchronically altered. One possibility is to exchange the polarizations of the signals sent out on the sub channels among themselves in pre-determined intervals.
It can also be anticipated, however, that for each signal sent out on the sub channels one out of a volume of pre-determined polarizations is in each case to be assigned a polarization selected by chance. Thus, no polarization can be assigned in duplicate.

In the event that the radio signal sent out on the MIMO channel is modulated by a digital multithread, the polarization exchange is directed such that the polarizations of the signals sent out on the sub channels for the duration of at least one bit of this

multithread remain the same. The polarization exchange can, however, also be controlled in such a way that the polarizations of the signals sent out on the sub channels shift one bit of the multithread at least once during the period.

The control facility assumes influence of the polarization of the signals sent out on the sub channels through corresponding facilities such as phase modifiers, delay lines, power splitters, whereby the polarizations are determined via the relationship of the amounts of their performances *a* as well as (*1-a*), and / or their mutual phase situation and / or their time disalignment t_1, t_2 is decided. The number of the switchable polarizations must be at least as large as the number *m* sub channels.

According to the invention, with one antenna each, which can send and receive several polarizations simultaneously, many uncorrelated MI and MO sub channels will be realized. The advantage of the MIMO method, which until now was achieved only by several spatially distributed antennas, is obtained according to the invention with only one antenna.
Preferably, the amounts of the timewise averaged correlation factors $\underline{r}$ of the MIMO channels can be reduced since the polarizations of the antennas are constantly being altered, whereby the polarizations with a digitally modulated radio signal:
- remain the same over at least one bit, or
- shifts at least once per bit.

If the sub channels are CDMA channels, the polarization shift refers to one chip.
In the following, simple exemplary embodiments of the invention are explained in more detail on the basis of the drawings.

Figure 1, by way of example, shows the general installation of a MIMO communications system according to the current state of the technology;

Figure 2, by way of example, shows an installation of a MIMI communications system;

Figure 3 shows the application of Y circulator at the installation in accordance with figure 2;

Figure 4 shows a special exemplary embodiment of a MIMO communications system according to the invention with utilization of a cross dipole;

Figure 5 shows a representation of the electric field of the wave of a cross dipole that is expanding in the direction *z*, that is vertically to the level of the dipole.

According to the invention, the decorrelation of the sub channels of a MIMO radio signal is obtained by polarization decoupling. The polarization of an even electromagnetic wave is generally sinistrorotary or dextrorotatory elliptically, in special cases linearly or circular. The rotational direction of the polarization is right-turning as defined by the IEEE if the peak of the electric field vector turns clockwise as viewed from the transmitter. The temporal dependence of the electric field vector underlies this definition at a fixed position.

The radio signals A, B, C from the radio equipment 1 in accordance with Figure 1 are conducted on only one antenna, instead of on several antennas, which superpositions and emits the signals with m different polarizations. Economization is thereby obtained by spatially offset antennas. The antenna consists of an antenna array with several partial antennas lying spatially densely together.

In the exemplary embodiment according to Figure 2, the MI radio signals A, B, C of the radio equipment 1 shown in Figure 1 are assigned with power splitters 6.1 to 6.3 on two branches each with the standardized performances a_i and $(1-a_i)$ with $0 \le a_i \le m$. Both dispatcher exits of each MI sub channel with the performances a_i

and (*1-a*$_i$) are delayed by the times t_i1 and t_i2 by means of delay lines 7.1 to 7.6 that can consist of, for example, switchable management pieces or phase modifiers. Through one exponential lag each in both branches of an MI sub channel, whereby in general $t_i1 = 0$ or $t_i2 = 0$, the wave can jump in each branch alternatively: thereby left or right turning polarization is generated with the antenna 8.
According to the adjustment values of a_i, t_i1 and t_i2, waves can be transmitted with any situation and direction of rotation of the polarization ellipse, including degeneracy to the rectilinear.

In order to avoid the mutual repercussion of the MI sub channels, the two branches for each MI channel are led over the directional coupler 10.1 to 10.6 on the antenna. The waves from the branches 1 of directional couplers 10.1, 10.3 and 10.5 are, for example, overlaid in a linearly polarized partial antenna A1, those from branches 2 of directional couplers 10.2, 10.4 and 10.6 in a partial antenna A2 with orthogonal polarization. The partial antennas A1 and A2 are very densely neighboring and form an antenna array. Preferably, the phase centers of the partial antennas coincide. As antennas, linearly or circularly polarized antennas with orthogonal polarization or horn emitters with a suitable mode of stimulation can be used.

The change over of polarization of the MI antenna takes place over several bits or several times per bit and is governed by a control facility 9.

For the shift of polarization, two algorithms are preferably provided:
1. Synchronous, cyclical change over of all MI channels (polarization of MI channel A is switched to MI channel B after a turn-around period: polarization of MI channel B is switched to MI channel C, etc.)
2. Polarization of the MI channels generated by chance.

The polarizations of the MI sub channels can, for example, be: horizontally, vertically, linearly with polarization under 45° and 135° to the ground, circularly left / right rotation, elliptically left / right rotation (with selectable axis relationship and situation to the ground), etc. The number of the switchable polarization conditions should be at least as large as the number m of the sub channels.

In order to avoid the mutual retroaction of the MI sub channels, both branches for each MI channel are conducted to the antenna via directional coupler 10.1 through 10.6 on the antenna parts A1 and A2. Alternatively, with two MI channels, two Y circulators and for m > 2 cascaded Y circulators can be used for the interconnection of the MI antennas (Figure 3).

As an exemplary embodiment of the decorrelation of MI sub channels with an antenna may be a cross dipole 11 considered as a simple exemplary embodiment in Figure 4. A cross dipole is considered as an interconnection of two linearly polarized, orthogonal dipoles 11.1 and 11.2, whose phase centers coincide.
As a directional antenna, the cross dipole can be arranged in front of a reflector.
Dipoles have the advantages:
- of a simpler constructive installation
- broadband ability via appropriate design of the dipoles (for example a ratio of diameter / length with cylindrical dipoles).

The performance of a transmitter 1 is divided up in the power splitter 6.1 (cf. also Figure 2) on the shares of power *a* and (*1-a*) apportioned. After the delay of the two signal components by t_1 and/or t_2 in the delay lines 7.1 and 7.2, the signals are conducted on the two dipoles 11.1 and 11.2. With practical implementations, the total length of a dipole generally amounts to approximately $\lambda/2$.

The electric field of a wave of the cross dipole 11 extending in the direction z, that is vertically to the dipole level, is described by the two-dimensional vector according to figures 4 and 5:

$\underline{E(t)} = ex \,.\, a \,.\, \cos(\omega.\, t - k.z + \delta_x) + ex \,.\, (1\text{-}a) \,.\, \cos(\omega.\, t - k.z + \delta_y)$

with the wave number $k = 2\pi/\lambda$ and the phase $\delta = 2.\pi.c.\tau_i /\lambda$

The following polarizations of MIMO antennas are, for example, possible with alignments t, t and a (see, for example: Kraus, John D.: "Antennas", 1950. and Schrott / Stein: "Bedeutung und Beschreibung der Polarization elektromagnetischer Wellen" = "Meaning and Description of the Polarization of Electromagnetic Waves", 1980,):

a	1	0	0.5	0.5	<1	< 1	0.5	0.5	0.5	0.5
T1	bel	bel	λ/4.c	0	λ/4.c	0	λ/2.c	0	< λ/2.c	0
T2	bel	bel	0	λ/4.c	0	λ/4.c	0	0	0	< λ/2.c
Pol	hor	vert	zir-re	zir-li	ell-re	ell-li	45°	135°	ell-re	ell-li

Table 1

(Pole: Polarization; bel: any: hor: horizontal; vert: vertical: zir-li: left-circular; zir-re: right-circular; ell-li: elliptically sinistrorotatory; ell-re: elliptically dextrorotatory; 45°: linearly below 45° to the ground: 135°: idem. under 135°)

The orientation angle φ of the elliptical main axis with respect to the ground amounts to:

$\tan 2t\ \varphi = 2a(a - 1)/(a2 - (1 - a)^2)\ .\cos \delta$

with the phase of the polarization relationship $\delta = \beta_y - \beta_x$.

The ellipticity angle as a measurement for the axis relationship of the ellipse (tangents of the axes) is defined by:

$\tan 2\delta = \tan\delta \cdot \sin 2\varphi$.

Thereby the form and situation of the polarization ellipse is established by a and τ_i.

It is advantageous that elliptical polarizations can be governed both by the division a and (1-a) of the transmission performance and the delay times τ_i (phase situation) of the signal, as well as, in narrower limits, only by τ, if $0 < a < 1$ is selected (see Table 1).

List of reference drawings

1. Base station (transmission - / reception equipment)
2. MI antennas
3. mobile station
4. MO antennas
5. MIMO sub channels
6. power splitters (6.1-6.3))
7. delay elements (71-7.8))
8. antenna (8.1, 8.2))
9. control equipment
10. directional coupler (10.1-10.6))
11. cross dipoles (11.1-11.2))
12. Y-circulator (12.1, 12.2))